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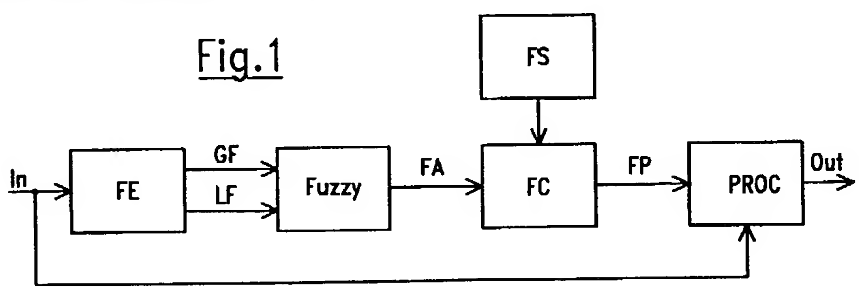
(54) **Post-processing method for reducing artifacts in block-coded digital images, and post-processing device for actuating such method**

(57) A post-processing method for reducing artifacts in block-coded digital images, characterized by providing for: dividing an input image (In) into a plurality of image blocks (IB); for each image block (IB), estimating global features (GF) of said image block providing information on an average content of image edges along the horizontal and vertical directions of said image block (IB); for each pixel (Px) of an image block (IB) under examination, estimating local features (LF) for said pixel (Px) providing information on the content of image edges along the horizontal and vertical directions of an image area near said pixel (Px); modifying the value of said pixel (Px) according to both said global features (GF) of the image block (IB) to which said pixel (Px) belongs and said local features (LF) of the image area near said pixel (Px).

Fig.1



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Description

The present invention relates digital image coding. More precisely, the invention relates to a post-processing method for reducing artifacts in block-coded digital images, and to a post-processing device suitable for actuating such a method.

With the diffusion of digital communication systems, digital images are more and more used. This has led to the diffusion of still and video cameras with digital acquisition and processing capability.

In order to better exploit storage means and transmission bandwidth, digital image compression standards have been developed, such as JPEG for still images, and MPEG-1 and MPEG-2 for digital television image sequences.

The above-referred compression standards provides for block-coding based on Discrete Cosine Transform (DCT). A digital image is divided into blocks of pixels, and each block is encoded independently from the others. DCT coefficients for the pixels of each block are evaluated and a quantization matrix is applied to the DCT coefficients to reduce the information to be stored or transmitted. When the image is to be displayed, it must be decoded in advance.

Due to the quantization process, these image compression methods are lossy, i.e. they cause a loss of information in the decoded image with respect to the original image. The decoded image can thus present noticeable degradation, mainly consisting of two kinds of artifacts known in the art under the names of "grid noise" and "staircase noise".

In order to reduce the image degradation, post-processing methods of the decoded image have been proposed which allow for attenuating grid noise and staircase noise.

In view of the state of the art described, it is an object of the present invention to provide a new post-processing method for reducing artifacts in block-coded digital images.

According to the present invention, such object is attained by means of a post-processing method for reducing artifacts in block-coded digital images, characterized by providing for:

a) dividing an input image into a plurality of image blocks;
b) for each image block, estimating global features of said image block providing information on an average content of image edges along the horizontal and vertical directions of said image block;
c) for each pixel of an image block under examination, estimating local features for said pixel providing information on the content of image edges along the horizontal and vertical directions of an image area around said pixel;
d) modifying the value of said pixel according to both said global features of the image block to which said pixel belongs and said local features of the image area around said pixel.

Also according to the invention, there is also provided a post-processing device for actuating said method, characterized by comprising:

- first means supplied with an input image for estimating global features of an image block under examination, said global features providing information on an average content of image edges along the horizontal and vertical directions of said image block;
- second means supplied with said input image for estimating local features for each pixel of the image block under examination, said local features providing information on the content of image edges along the horizontal and vertical directions of an image area around said pixel;
- third means supplied with said global features and said local features for modifying the value of said pixel according to both said global features and said local features.

The features and advantages of the present invention will be made apparent from the following detailed description of an embodiment thereof, illustrated as a non-limiting example in the annexed drawings, wherein:

Figure 1 is a schematic block diagram illustrating the principle of operation of a method according to the present invention;
Figure 2 shows a digital image divided into image blocks;
Figure 3 shows in detail an image block into which the digital image of Figure 2 is divided;
Figure 4 shows an array of pixels of the image block of Figure 3;
Figure 5 shows an image sub-block of the image block of Figure 3 used for evaluating global features of the image block;
Figure 6 shows an horizontal processing window used for evaluating local features in the horizontal direction for a generic pixel of the image block;
Figure 7 shows a vertical processing window used for evaluating local features in the vertical direction for said generic pixel;
Figures 8 and 9 shows two membership functions used to perform a fuzzy computation;

Figure 10 is a block diagram of a device according to the present invention;
Figure 11 shows the structure of two blocks of the device of Figure 10; and
Figure 12 is a block diagram of other two blocks of the device of Figure 10.

With reference to Figure 1, there is shown a block diagram illustrating the principle of operation of the post-processing method according to the present invention. An input decoded compressed digital image In is supplied to a Feature Extraction block FE. Block FE provides for analyzing the image to evaluate global and local features thereof. The global and local features, respectively GF and LF, of the image In evaluated by block FE are supplied as inputs to a Fuzzy Process block FUZZY which, according to fuzzy rules, determines parameters FA suitable for determining the kind of filtering to be performed, in accordance to the global and local features GF and FL of the image. The parameters FA calculated by block FUZZY are supplied to a Filter Composition block FC which according to said parameters FA determines the type of filtering to performed out of a set of predefined filters (block FS). Filter parameters FP determined by block FC are then supplied to a Processing block PROC, also supplied directly with the input image In, which performs the filtering of the input image In according to the filter parameters FP to provide a post-processed output image Out.

It appears that the kind of filtering to be performed on the decoded input image In is chosen after an estimation of the global and local features of the decoded input image. For image areas near grid noise and near an edge, a low-pass filtering is performed, to reduce both staircase noise and grid noise. For areas containing fine details (image edges and texture), no filtering is performed. Thus, the method according to the present invention provides for performing a non-linear adaptive filtering on the pixels of the decoded image.

The principle of operation outlined above will be now described in detail.

As shown in Figure 2, the input image In is partitioned into image blocks IB, each containing an equal number of pixels. A typical dimension of the blocks is 8*8 pixels (Figure 3), but this is not however to be intended as a limitation, since other block dimensions are suitable.

The image blocks IB of the input image In are scanned line by line starting from the top-left block to the bottom-right one. For each image block IB, the Feature Extraction block FE in Figure 1 determines the global and local features GF and LF.

Global features of the image block IB under examination are determined by applying horizontal and vertical Sobel operators:

$$\text{horizontal Sobel operator (Hsob):} \begin{bmatrix} h11 & h12 & h13 \\ h21 & h22 & h33 \\ h31 & h32 & h33 \end{bmatrix};$$

$$\text{vertical Sobel operator (Vsob):} \begin{bmatrix} v11 & v12 & v13 \\ v21 & v22 & v23 \\ v31 & v32 & v33 \end{bmatrix}$$

to each pixel belonging to an image sub-block internal to the image block IB. For example, the following Sobel operators:

$$\text{Hsob:} \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix};$$

$$\text{Vsob:} \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

are applied to a 6*6 pixel image sub-block ISB (gray area in Figure 5). As shown in Figure 4, for each pixel Pi of the image sub-block ISB a 3*3 array of neighboring pixels M centered in pixel Pi is considered, and the values of the pixels of said array M are multiplied by the coefficients of the horizontal and vertical Sobel operators, to obtain:

$$Hsob = (P3+P8+2*P5) - (P1+P6+2*P4),$$

$$Vsob = (P6+P8+2*P7) - (P1+P3+2*P2),$$

where P1-P4 and P5-P8 are the values of the pixels (gray levels).

As known, horizontal and vertical Sobel operators perform a filtering capable of detecting edges along the horizontal and vertical direction, respectively.

The output values of the horizontal Sobel operators calculated for the pixels of image sub-block ISB are accumulated to obtain an accumulated value Acc(Hsob), and the output values of the vertical Sobel operators calculated for the pixels of image sub-block ISB are accumulated to obtain an accumulated value Acc(Vsob). Acc(Hsob) gives the high-frequency content in the horizontal direction (vertical edges) of the image block IB. Acc(Vsob) gives the high-frequency content in the vertical direction (horizontal edges) of image block IB. Thus, Acc(Hsob) and Acc(Vsob) respectively provide the degree of "edgeness" of the image block under examination in the vertical and horizontal directions. It is to be noted that in order to evaluate the global features GF of the image block IB under examination, only the pixels belonging to this block are considered (by applying 3*3 Sobel operators to the 6*6 image sub-block ISB, it is not necessary to take into consideration pixels belonging to neighboring image blocks).

Global features GF of the image block under examination can be formed by the accumulated values Acc(Hsob) and Acc(Vsob). Alternatively, the global features GF of the image block can be formed by an average of the accumulated values Acc(Hsob) and Acc(Vsob), to obtain the average number of edges in the horizontal and vertical directions in the image block under examination.

Local features LF of the image block IB are estimated according to the following method. All the pixels of the image block IB under examination are scanned line by line starting from the top-left pixel down to the bottom-right one. To each pixel a horizontal processing window is applied: a prescribed number of pixels respectively preceding and following the pixel under consideration and belonging to the same image line of the pixel under consideration is considered. A suitable horizontal processing window HPW is shown in Figure 6, which is a horizontal 1*5 processing window: for a given pixel, the two preceding pixels Pa, Pb and the two following pixels Pc, Pd belonging to the same line are considered. In Figure 6 there is shown by way of example the horizontal processing window HPW associated to the first pixel Px of the image block. It should be noted that not only the pixels of the image block IB under examination are considered, but also pixels belonging to neighboring image blocks; this is for example the case of the first, second, seventh and eight pixel of each line of pixels of the image block IB under examination.

The horizontal Sobel operator Hsob previously mentioned is applied to each pixel Pa, Pb, Px, Pc, Pd in the horizontal processing window HPW, to obtain five output values HS1-HS5. Values HS1-HS5 provide the local features in the horizontal direction for the pixel under examination Px, i.e. the high-frequency content in the horizontal direction of the image region around the pixel under examination.

Similarly, a vertical processing window is applied to each pixel of the image block IB. The vertical processing window is formed by the pixel under consideration Px, and a prescribed number of pixels belonging to the same column as and preceding and following the pixel under consideration; for example, as shown in Figure 7 the vertical processing window VPW can have dimensions identical to the horizontal processing window HPW (5*1), and thus contains two pixels Pe, Pf preceding pixel Px and two pixels Pg, Ph following pixel Px in the vertical direction.

The vertical Sobel operator Vsob previously mentioned is then applied to each pixel of the vertical processing window VPW to obtain five output values VS1-VS5. Values VS1-VS5 form the local features in the vertical direction for the pixel under examination, i.e. the high-frequency content in the vertical direction of an image region around the pixel under examination.

The global features GF for the image block IB under examination (i.e., the two accumulated values Acc(Hsob) and Acc(Vsob) or, in alternative, the average value of Acc(Hsob) and Acc(Vsob)) and the local features LF for the pixel under examination inside said image block (the ten values HS1-HS5 and VS1-VS5) are then supplied to the Fuzzy Process block FUZZY. This block provides for evaluating the degree of membership of a generic value HSi and Vsi (i=1..5) to two fuzzy sets "Small" and "Big"; these degree of membership can be evaluated by applying to HSi, VSi the membership functions depicted in Figures 8 and 9. In these figures, Th1 and Th2 are values depending on the global features GF of the image block under examination, i.e. on the accumulated values Acc(Hsob) and Acc(Vsob) or on the average of the accumulated values; in the first case, Th1 and Th2 are different for the Hsi and Vsi values; in the second case, Th1 and Th2 are the same for Hsi and Vsi values.

Fuzzy rules having as antecedents the degrees of membership of the output values HSi and VSi to the two fuzzy sets "Small" and "Big" are then evaluated. This means that 32 rules are to be evaluated for both the horizontal and vertical directions. However, all those fuzzy rules having the same consequence are synthesized in one rule only by an else operator. In this way, the system complexity is reduced, and a total of nine rules for each direction have to be evaluated.

The following fuzzy rules are applied to the five values HS1-HS5 associated to the horizontal direction:

1. *If HS1 is* Small *and HS2 is* Small *and HS3 is* Small *and HS4 is* Small *and HS5 is* Small, *then* $\alpha 1$ *is* Big;
2. *If HS1 is* Small *and HS2 is* Small *and HS3 is* Small *and HS4 is* Small *and HS5 is* Big, *then* $\alpha 2$ *is* Big;

3. *If* HS1 *is* Small *and* HS2 *is* Small *and* HS3 *is* Small *and* HS4 *is* Big *and* HS5 *is* Small, *then* α3 *is* Big;
4. *If* HS1 *is* Small *and* HS2 *is* Small *and* HS3 *is* Small *and* HS4 *is* Big *and* HS5 *is* Big, *then* α4 *is* Big;
5. *If* HS1 *is* Small *and* HS2 *is* Big *and* HS3 *is* Small *and* HS4 *is* Small *and* HS5 *is* Small, *then* α5 *is* Big;
6. *If* HS1 *is* Big *and* HS2 *is* Small *and* HS3 *is* Small *and* HS4 *is* Small *and* HS5 *is* Small, *then* α6 *is* Big;
7. *If* HS1 *is* Big *and* HS2 *is* Small *and* HS3 *is* Small *and* HS4 *is* Small *and* HS5 *is* Big, *then* α7 *is* Big;
8. *If* HS1 *is* Big *and* HS2 *is* Big *and* HS3 *is* Small *and* HS4 *is* Small *and* HS5 *is* Small, *then* α8 *is* Big.

The activation level of each rule depends on the degree of memberships of the pattern of output values HSi of the horizontal Sobel operator applied to the five pixels of the horizontal processing window HPW; the degree of memberships depend in turn on the global features GF of the image block to which the pixel under examination belongs. The activation level of the else (ninth) rule is computed as αelse = (1 - αave) , where αave is the average activation degree of fuzzy rules 1 to 8. α1 to α8 and αelse, and a similar set of nine activation degrees for the fuzzy rules applied to values VS1-VS5) form the output FA of the fuzzy process block FUZZY in Figure 1.

Each one of the above-listed rules is associated to a respective set of predefined filter parameters, which are stored as a look-up table in block FS of Figure 1. Suitable predefined filter parameter sets are for example:

Rule 1: (c11=1.0, c12=1.0, c13=1.0, c14=1.0, c15=1.0) if the pixel under examination lies outside the image sub-block ISB, and (c11=0.0, c12=1.0, c13=1.0, c14=1.0, c15=0.0) if the pixel under examination lies inside the image sub-block ISB;
Rule 2: (c21=0.5, c22=1.0, c23=1.0, c24=1.0, c25=0.0);
Rule 3: (c31=0.5, c32=1.0, c33=1.0, c34=0.0, c35=0.0);
Rule 4: (c41=0.5, c42=1.0, c43=1.0, c44=0.0, c45=0.0);
Rule 5: (c51=0.0, c52=0.0, c53=1.0, c54=1.0, c55=0.5);
Rule 6: (c61=0.0, c62=1.0, c63=1.0, c64=1.0, c65=0.5);
Rule 7: (c71=0.0, c72=1.0, c73=1.0, c74=1.0, c75=0.0);
Rule 8: (c81=0.0, c82=0.0, c83=1.0, c84=1.0, c85=0.5);
Else rule: (c91=0.0, c92=0.0, c93=1.0, c94=0.0, c95=0.0).

The parameters FP of the filter to be applied to the five pixels of the horizontal processing window HPW are calculated as a weighted average of the nine filters described above, with weight factors formed by the activation degrees α1 to α8 and αelse of the respective fuzzy rules.

Assuming that αi is the activation degree of the i-th fuzzy rule (i=1..9), the ninth fuzzy rule being the else fuzzy rule (α9 = αelse), and cij are the coefficients of the i-th filter (i=1..9, j=1..5), the weight factor applied to the i-th filter, associated to the i-th fuzzy rule is:

$$Fi = \alpha i \cdot cij$$

and the coefficients Hj of the final horizontal filter to be applied to the pixels of the horizontal processing window HPW are given by:

$$Hj = \frac{\sum_{i=1}^{9} \alpha i \cdot cij}{N}$$

where N is a normalization factor.

The horizontally-filtered value $\underline{Px}$ of the pixel Px under examination (at the center of the horizontal processing window) is then calculated as a weighted average of the values of the pixels Pa, Pb, Px, Pc and Pd belonging to the horizontal processing window HPW, with weight factors formed by the coefficients Hj:

$$\underline{Px} = H1{*}Pa + H2{*}Pb + H3{*}Px + H4{*}Pc + H5{*}Pd.$$

Similar calculations are performed for the vertical direction, starting from the output values VS1-VS5 of the vertical Sobel operators applied to the pixels Pe, Pf, Px, Pg and Ph in the vertical processing window VPW. The coefficients Vj (j=1..5) of the filter for the vertical direction are calculated in a way completely similar to that used for determining the coefficients Hj:

$$V_j = \frac{\sum_{i=1}^{9} \beta_i \cdot c_{ij}}{N}$$

where β_i (i=1..9) are the activation degrees of nine fuzzy rules for the vertical direction (similar to those listed above for the horizontal direction) and c_{ij} (j=1..5) now are the predefined filter parameters associated to the i-th fuzzy rule for the vertical direction. The coefficients Vj are then applied to the pixels in the vertical processing window VPW to calculate a weighted average of the same. The filtered value of the pixel Px under examination, filtered in both the horizontal and vertical direction, is provided at the output Out of the processing block PROC.

The value of the pixel Px under examination to be multiplied by the vertical filter coefficient V3 can be the value $\underline{Px}$ obtained after having applied to the pixels in the horizontal processing window HPW the horizontal filter Hj (j=1..5):

$$Out = V1{*}Pe + V2{*}Pf + V3{*}\underline{Px} + V4{*}Pg + V5{*}Ph.$$

Alternatively, it is possible to evaluate first the vertically-filtered value $\underline{\underline{Px}}$ of the pixel under examination:

$$\underline{\underline{Px}} = V1{*}Pe + V2{*}Pf + V3{*}Px + V4{*}Pg + V5{*}Ph,$$

and then performing the filtering in the horizontal direction applying to this value the respective coefficient H3 of the horizontal filter Hj:

$$Out = H1{*}Pa + H2{*}Pb + H3{*}\underline{\underline{Px}} + H4{*}Pc + H5{*}Pd.$$

The sequence is of no importance, the important thing to be underlined being that at the end of the process the value of the pixel under examination is the result of both an horizontal and a vertical filtering.

Figure 10 is a block diagram of a device suitable for actuating the method previously described. The device comprises two main blocks: a first block 1 evaluates the global features GF of the image blocks IB the image to be post-processed is divided in, and a second block 2 evaluates the local features LF of the pixels of the image and performs the filtering according to both the global features and the local features.

It is assumed that the image to be post-processed is scanned line by line in a sequential order. Signal In is a stream of pixels of the input image scanned line by line. Block 1 is supplied with signal In; signal In also supplies a cascade of two line memories LM1 and LM2 whose outputs supplies block 1.

Inside block 1, signal In and the outputs of line memories LM1 and LM2 supply a block 3 of pixel delays suitable for implementing a 3*3 pixel window which is used to calculate horizontal and vertical Sobel operators for the pixels of the 6*6 image sub-block ISB inside each image block IB. Block 3 supplies a block 4 which calculates the outputs Hsob and Vsob of the horizontal and vertical Sobel operators for those pixels of the current image line belonging to the 6*6 image sub-blocks ISB of each image block IB. The outputs Hsob and Vsob of block 4 are supplied to an accumulator block 5 wherein they are accumulated. After eight image lines, i.e. a line of image blocks IB, have been scanned, the accumulated values Acc(Hsob), Acc(Vsob) (or alternatively the average thereof) for each image block IB are stored in a memory block 6.

The output of line memory LM2 supplies a cascade of eight further line memories LM3-LM10. Block 2 is supplied in parallel with the outputs of line memories LM4-LM10. In this way, evaluation of the local features and calculation of the filter parameters starts after block 1 has estimated the global features GF for a line of image blocks IB.

Inside block 2, a block 7 of pixel delays is supplied with the outputs of line memories LM4-LM10; by means of the line memories LM4-LM10 and the pixel delay block 7 it is possibile to implement the 5*1 vertical processing window VPW. The outputs L4-L10 of the pixel delays block 7 supply a block 8 which applies the vertical Sobel operator to each pixel inside the vertical processing window VPW. To avoid the use of further line memories, a parallel approach is preferred providing for calculating five vertical Sobel operators in parallel; the outputs of the five vertical Sobel operators VS1-VS5 are supplied to a vertical fuzzy filter 9, which is also supplied with the outputs L6-L10 of the pixel delay block 7 and the output MOUT of the memory MEM of block 1. MOUT supplies the global features GF of the image block IB currently processed by block 2, i.e. the accumulated value Acc(Vsob) or, alternatively, the average of Acc(Vsob) and Acc(Hsob). The vertical fuzzy filter block 9 evaluates the degree of membership of values VS1-VS5 to the fuzzy sets "Small" and "Big" taking into account the global features provided by MOUT, evaluates the activation levels of the nine fuzzy rules for the vertical direction, calculates the coefficients Vj (j=1..5) of the vertical filter and applies the vertical filter coefficients Vj to the five pixels Pe, Pf, Px, Pg, Ph in the vertical processing window VPW, to calculate the vertically-filtered value $\underline{\underline{Px}}$ of the pixel in the middle of the vertical processing window. The output of the vertical fuzzy filter block 9 forms the vertically-filtered value $\underline{\underline{Pd}}$ of pixel Pd in the horizontal processing window HPW shown in Figure 6 and sup-

plies directly a horizontal fuzzy filter block 10; the output Pd of block 9 also supplies a cascade of four pixel delays D whose outputs respectively form the vertically-filtered values Pc, Px, Pb, Pa of the pixels Pc, Px, Pb, Pa in the horizontal processing window HPW and supply the horizontal fuzzy filter block 10.

In parallel to blocks 8 and 9, the outputs L7-L9 of the pixel delay block 7 supply a block 11 which applies the horizontal Sobel operators to the pixels inside the horizontal processing window HPW. Differently from the vertical sobel operators, only one horizontal sobel operator is calculated at a time; a compensation delay block 12 introduces a delay for compensating the processing delay of the vertical fuzzy filter block 9. The output of block 12, forming the output of the horizontal Sobel operator HS5 applied to pixel Pd of the horizontal processing window in Figure 6, supplies the horizontal fuzzy filter block 10 and a cascade of four pixel delays D, the outputs thereof forming the values HS4, HS3, HS2 and HS1 and suppling the horizontal fuzzy filter block 10. The horizontal fuzzy filter block 10, which is also supplied by the output MOUT of the memory block MEM in block 1 providing the value Acc(Hsob) (or alternatively the average of values Acc(Hsob) and Acc(Vsob)), evaluates the degree of membership of values HS1-HS5 to the fuzzy sets "Small" and "Big" according to the value of the global features GF provided by MOUT, evaluates the activation levels of the nine fuzzy rules described above for the filtering in the horizontal direction, calculates the coefficients Hj of the horizontal filter and applies the parameters Hj to the vertically-filtered values Pa, Pb, Px, Pc, Pd of the pixels Pa, Pb, Px, Pc, Pd in the horizontal processing window HPW to obtain the horizontally- and vertically-filtered value Out of the pixel Px under examination.

A control circuit CTRL controls the operation of blocks 1, 2 and the line memories LM1-LM10.

Figure 11 shows the structure of the vertical and horizontal Sobel operator blocks 8 and 11 of Figure 10. They are composed in a straightforward way by adders.

Figure 12 shows the structure of both the vertical fuzzy filter block 9 and the horizontal fuzzy filter block 10. X1-X5 are the vertical or, respectively, horizontal Sobel operator outputs VS1-VS5 and HS1-HS5. X1-X5 are supplied to a fuzzy rule evaluation block 13 which evaluates the activation degrees $\beta1$-$\beta9$ of the nine fuzzy rules for the vertical direction or, respectively, the activation degrees $\alpha1$-$\alpha9$ of the nine fuzzy rules for the horizontal direction. The activation degrees evaluated by block 13 are supplied to a look-up table of respective predefined filter parameters F1-F9 (forming block FS in Figure 1), and the outputs of the look-up table, i.e. the predefined filter parameters cij multiplied by the activation degree of the respective fuzzy rule, are supplied to a filter composition block 14 which calculates the coefficients V1-V5 or, respectively, H1-H5, of the vertical or, respectively, horizontal filter. Said coefficients are then supplied to a processing block 15 which is also supplied with the pixel values PXS (L6-L10 or, respectively, Pa, Pb, Px, Pc, Pd in Figure 10); block 15 applies the filter coefficients to the pixel values to obtain the filtered value of the pixel under examination Px.

Claims

1. Post-processing method for reducing artifacts in block-coded digital images, characterized by providing for:

   a) dividing an input image (In) into a plurality of image blocks (IB);
   b) for each image block (IB), estimating global features (GF) of said image block providing information on an average content of image edges along the horizontal and vertical directions of said image block (IB);
   c) for each pixel (Px) of an image block (IB) under examination, estimating local features (LF) for said pixel (Px) providing information on the content of image edges along the horizontal and vertical directions of an image area near said pixel (Px);
   d) modifying the value of said pixel (Px) according to both said global features (GF) of the image block (IB) to which said pixel (Px) belongs and said local features (LF) of the image area near said pixel (Px).

2. Method according to claim 1, characterized in that step d) provides for:

   d1) defining a set of predefined local features;
   d2) determining degrees of coincidence ($\alpha1$-$\alpha9$,$\beta1$-$\beta9$)of said local features (LF) of the image area around said pixel (Px) with each predefined local features of said set, said degrees of coincidence ($\alpha1$-$\alpha9$,$\beta1$-$\beta9$) depending on said global features (GF) of the image block (IB) to which said pixel (Px) belongs;
   d3) making the value of said pixel (Px) equal to a weighted average (Px,Px) of the value of said pixel (Px) and of the values of neighboring pixels (Pa-Pd,Pe-Pf), with weight factors (H1-H5,V1-V5) depending on said degrees of coincidence of said local features (LF) with each of said predefined local features.

3. Method according to claim 2, characterized in that said determining the degrees of coincidence ($\alpha1$-$\alpha9$,$\beta1$-$\beta9$) in step d2) provides for performing a fuzzy calculation.

4. Method according to claim 3, characterized in that each of said predefined local features is associated to a respective group of predefined weight factors (cij), and each of said weight factors (H1-H5,V1-V5) is calculated as a weighted average of corresponding predefined weight factors (cij) of said groups with weight coefficients (α1-α9,β1-β9) depending on said degrees of coincidence of said local features (LF) with each of said predefined local features.

5. Method according to claim 4, characterized in that said estimating global features (GF) of the image block (IB) under examination provides for applying horizontal and vertical Sobel operators (Hsob,Vsob) to pixels belonging to an image sub-block (ISB) internal to said image block (IB) under examination.

6. Method according to claim 5, characterized in that said estimating global features (GF) of the image block (IB) under examination provides for adding outputs of the horizontal Sobel operators (Hsob) applied to each pixel of said image sub-block (ISB) to obtain an accumulated output of horizontal Sobel operators (Acc(Hsob)), and adding outputs of the vertical Sobel operators (Vsob) applied to each pixel of said image sub-block (ISB) to obtain an accumulated output of vertical Sobel operators (Acc(Vsob)).

7. Method according to claim 6, characterized in that said global features (GF) of the image block (IB) under examination are formed by said accumulated outputs of the horizontal and vertical Sobel operators (Acc(Hsob),Acc(Vsob)).

8. Method according to claim 6, characterized in that said global features (GF) of the image block (IB) under examination are formed by an average of said accumulated outputs of the horizontal and vertical Sobel operators (Acc(Hsob),Acc(Vsob)).

9. Method according to claim 7 or 8, characterized in that said estimating local features (LF) for a pixel (Px) of the image block (IB) under examination provides for:

c1) considering an horizontal processing window (HPW) containing the pixel (Px) under examination and neighboring pixels (Pa,Pb,Pc,Pd) belonging to a same image line as the pixel (Px) and preceding and following the pixel (Px);
c2) applying said horizontal Sobel operator (Hsob) to each pixel (Pa-Pd,Px) of the horizontal processing window (HPW) to obtain a horizontal pattern of horizontal Sobel operator outputs (HS1-HS5);
c3) considering a vertical processing window (VPW) containing the pixel (Px) under examination and neighboring pixels (Pe,Pf,Pg,Ph) belonging to a same column of pixels as the pixel (Px) and preceding and following the pixel (Px);
c4) applying said vertical Sobel operator (Vsob) to each pixel (Pe-Ph,Px) of the vertical processing window (VPW) to obtain a vertical pattern of vertical Sobel operator outputs (VS1-VS5).

10. Method according to claim 9, characterized in that said horizontal and vertical processing windows (HPW,VPW) contains each one five pixels and are centered at said pixel (Px) under examination.

11. Method according to claim 10, characterized in that step d2) provides for determining degrees of membership of each horizontal Sobel operator output (HS1-HS5) of the horizontal pattern to a first fuzzy set "Small" and to a first fuzzy set "Big", evaluating activation degrees (α1-α9) of a first set of fuzzy rules each one associated with at least one predefined horizontal pattern of horizontal Sobel operator outputs, determining degrees of membership of each vertical Sobel operator output (VS1-VS5) of the vertical pattern to a second fuzzy set "Small" and to a second fuzzy set "Big" and evaluating activation degrees (β1-β9) of a second set of fuzzy rules each one associated with at least one predefined vertical pattern of vertical Sobel operator outputs.

12. Method according to claim 11, characterized in that said determining degrees of membership of the horizontal Sobel operator outputs (HS1-HS5) of the horizontal pattern to said first fuzzy sets "Small" and "Big" provides for determining a first and a second membership functions depending on said global features (GF), and said determining degrees of membership of the vertical Sobel operator outputs (VS1-VS5) of the vertical pattern to said second fuzzy sets "Small" and "Big" provides for determining a third and fourth membership functions depending on said global features (GF).

13. Method according to claim 12, characterized in that said groups of predefined weight factors (cij) comprise groups of predefined horizontal weight factors and groups of predefined vertical weight factors, each fuzzy rule of said first

set being associated with a respective one of said groups of predefined horizontal weight factors, and each fuzzy rule of said second set being associated with a respective one of said groups of predefined vertical weight factors.

14. Method according to claim 13, characterized in that said weight factors (H1-H5,V1-V5) comprise horizontal weight factors (H1-H5) and vertical weight factors (V1-V5), said horizontal weight factors (H1-H5) being determined by making a weighted average of the predefined horizontal weight factors with weight coefficients being formed by the activation degrees (α1-α9) of the fuzzy rules of the first set, and said vertical weight factors (V1-V5) being determined by making a weighted average of the predefined vertical weight factors with weight coefficients formed by the activation degrees (β1-β9) of the fuzzy rules of the second set.

15. Method according to claim 14, characterized in that the value of the pixel (Px) under examination is modified by applying the horizontal weight factors (H1-H5) to the values of the pixels (Pa-Pd,Px) in the horizontal processing window (HPW) and applying the vertical weight factors (V1-V5) to the values of the pixels (Pe-Ph,Px) in the vertical processing window (VPW).

16. Post-processing device for reducing artifacts in block-coded digital images, characterized by comprising:

- first means (1) supplied with an input image (In) for estimating global features (MOUT) of an image block (IB) under examination, said global features providing information on an average content of image edges along the horizontal and vertical directions of said image block (IB);
- second means (7,8,11,12,D) supplied with said input image (In) for estimating local features (VS1-VS5,HS1-HS5) for each pixel (Px) of the image block (IB) under examination, said local features providing information on the content of image edges along the horizontal and vertical directions of an image area around said pixel (Px);
- third means (9,D,10) supplied with said global features (MOUT) and said local features (VS1-VS5,HS1-HS5) for modifying the value of said pixel (Px) according to both said global features (MOUT) and said local features (VS1-VS5,HS1-HS5).

17. Device according to claim 16, characterized in that said first means (1) comprises means (3,4) for evaluating horizontal and vertical Sobel operator outputs (Hsob,Vsob) of horizontal and vertical Sobel operators applied to pixels of an image sub-block (ISB) internal to said image block (IB) under examination, and accumulator means (5) for accumulating the horizontal Sobel operator outputs (Hsob) and the vertical Sobel operator outputs (Vsob) for each pixel of the image sub-block (ISB).

18. Device according to claim 17, characterized in that said second means (7,8,11,12,D) comprises fourth means (7,8) for evaluating vertical Sobel operator outputs (VS1-VS5) of vertical Sobel operators (Vsob) applied to said pixel (Px) and to vertically-neighboring pixels (Pe,Pf,Pg,Ph) preceding and following the pixel (Px) in the vertical direction, and fifth means (11,12,D) for evaluating horizontal Sobel operator outputs (HS1-HS5) of horizontal Sobel operators (Hsob) applied to said pixel (Px) and to horizontally-neighboring pixels (Pa,Pb,Pc,Pd) preceding and following the pixel (Px) in the horizontal direction.

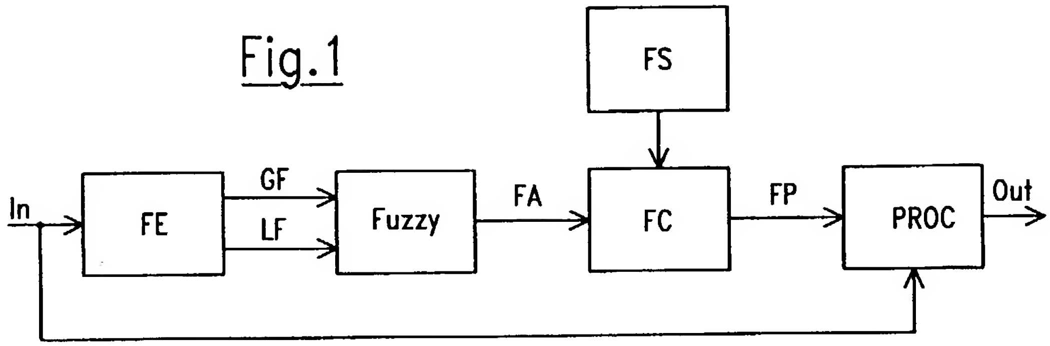
19. Device according to claim 18, characterized in that said third means (9,D,10) comprises vertical filter means (9,D) supplied with said vertical Sobel operator outputs (VS1-VS5) and said global features (MOUT) for calculating a vertically-filtered value ($\underline{Px}$) of said pixel (Px) depending on said global features (MOUT), said vertical Sobel operator outputs (VS1-VS5) and the values of said vertically-neighboring pixels (Pe,Pf,Pg,Ph), and horizontal filter means (10) supplied with said global features (MOUT), said horizontal Sobel operator outputs (HS1-HS5) and said vertically-filtered value ($\underline{Px}$) of said pixel (Px) for calculating a horizontally-filtered value of said pixel (Px) depending on said global features (MOUT), said horizontal Sobel operator outputs (HS1-HS5) and the vertically-filtered values ($\underline{Pa}$,$\underline{Pb}$,$\underline{Px}$,$\underline{Pc}$,$\underline{Pd}$) of said pixel (Px) and said horizontally-neighboring pixels (Pa,Pb,Pc,Pd).

20. Device according to claim 19, characterized in that said vertical filter means (9,D) comprises first fuzzy computation means (13) supplied with said vertical Sobel operator outputs (VS1-VS5) and said global features (MOUT) for evaluating degrees of coincidence (β1-β9) of the pattern of vertical Sobel operator outputs (VS1-VS5) with a set of predefined patterns of vertical Sobel operator outputs, said degrees of coincidence (β1-β9) depending on said global features (MOUT), a look-up table of predefined vertical filter coefficients (F1-F9) each one associated to at least one respective predefined pattern of vertical Sobel operator outputs, a vertical filter coefficients composition means (14) supplied with said predefined vertical filter coefficients for generating a set of vertical filter coefficients (V1-V5) which are a weighted average of the predefined vertical filter coefficients with weight coefficients formed by said degrees of coincidence (β1-β9), and a vertical filter (15) supplied with said vertical filter coefficients (V1-V5) and

the values of the pixel (Px) and the vertically-neighboring pixels (Pe,Pf,Pg,Ph) for providing at an ouput (FOUT) said vertically-filtered value of the pixel (Px).

21. Device according to claim 20, characterized in that said horizontal filter means (10) comprises second fuzzy computation means (13) supplied with said horizontal Sobel operator outputs (HS1-HS5) and said global features (MOUT) for evaluating degrees of coincidence (α1-α9) of the pattern of horizontal Sobel operator outputs (HS1-HS5) with a set of predefined patterns of horizontal Sobel operator outputs, said degrees of coincidence (α1-α9) depending on said global features (MOUT), a look-up table of predefined horizontal filter coefficients (F1-F9) each one associated to at least one respective predefined pattern of horizontal Sobel operator outputs, a horizontal filter coefficients composition means (14) supplied with said predefined horizontal filter coefficients (F1-F9) for generating a set of horizontal filter coefficients (H1-H5) which are a weighted average of the predefined horizontal filter coefficients with weight coefficients formed by said degrees of coincidence (α1-α9), and a horizontal filter (15) supplied with said horizontal filter coefficients (H1-H5) and the vertically-filtered values (Pa,Pb,Px,Pc,Pd) of the pixel (Px) and the horizontally-neighboring pixels (Pa,Pb,Pc,Pd) for providing at an ouput (FOUT) said horizontally-filtered value (Out) of the pixel (Px).

Fig.1



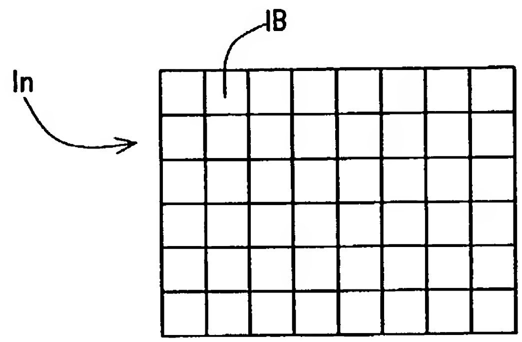


Fig.2

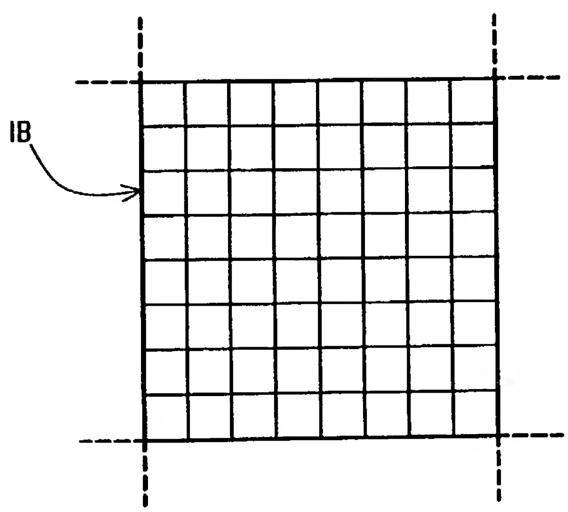


Fig.3

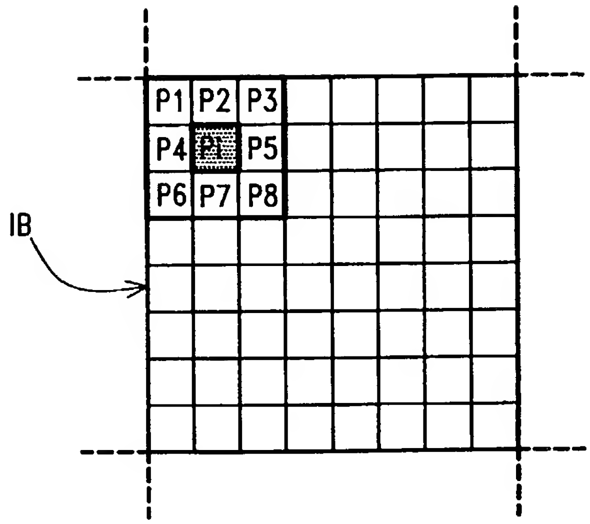


Fig.4

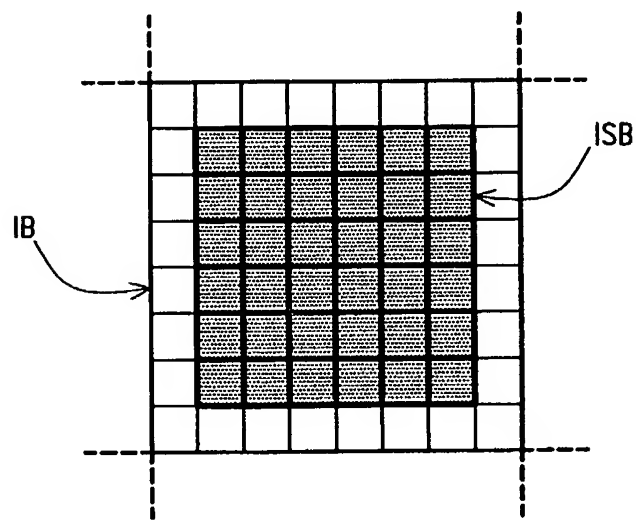


Fig.5

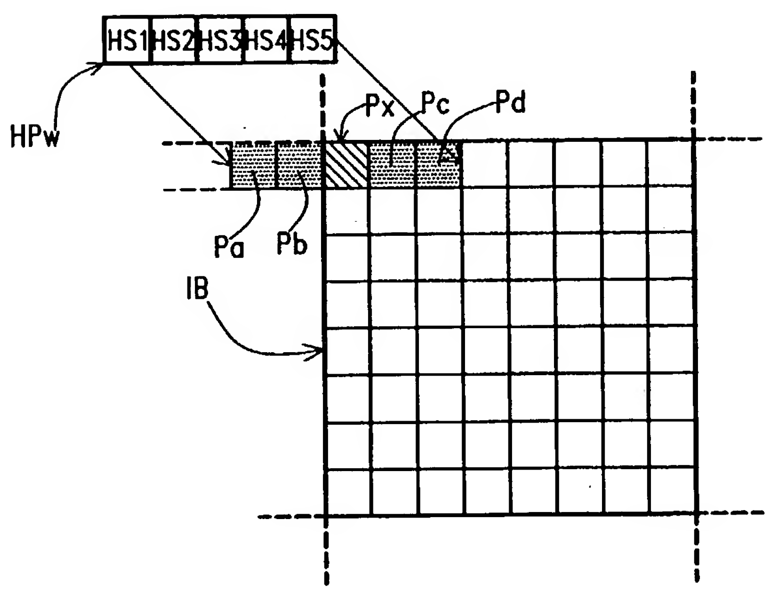


Fig.6

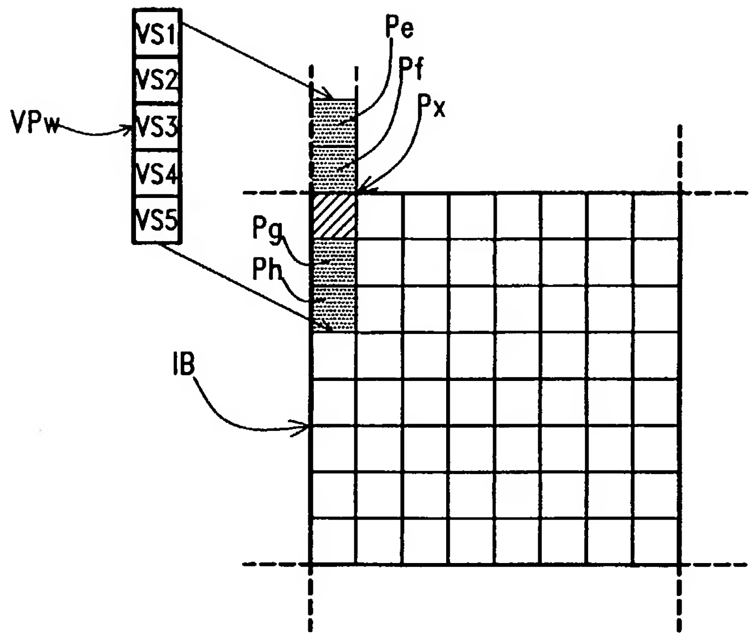


Fig.7

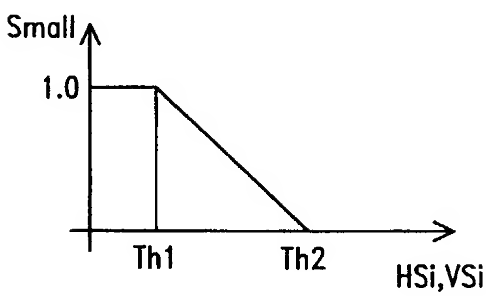


Fig.8

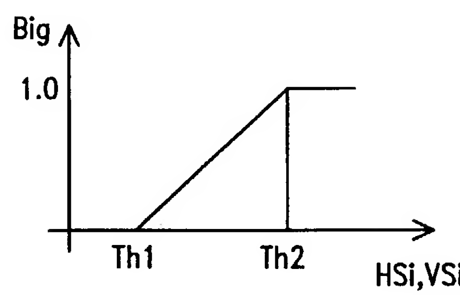
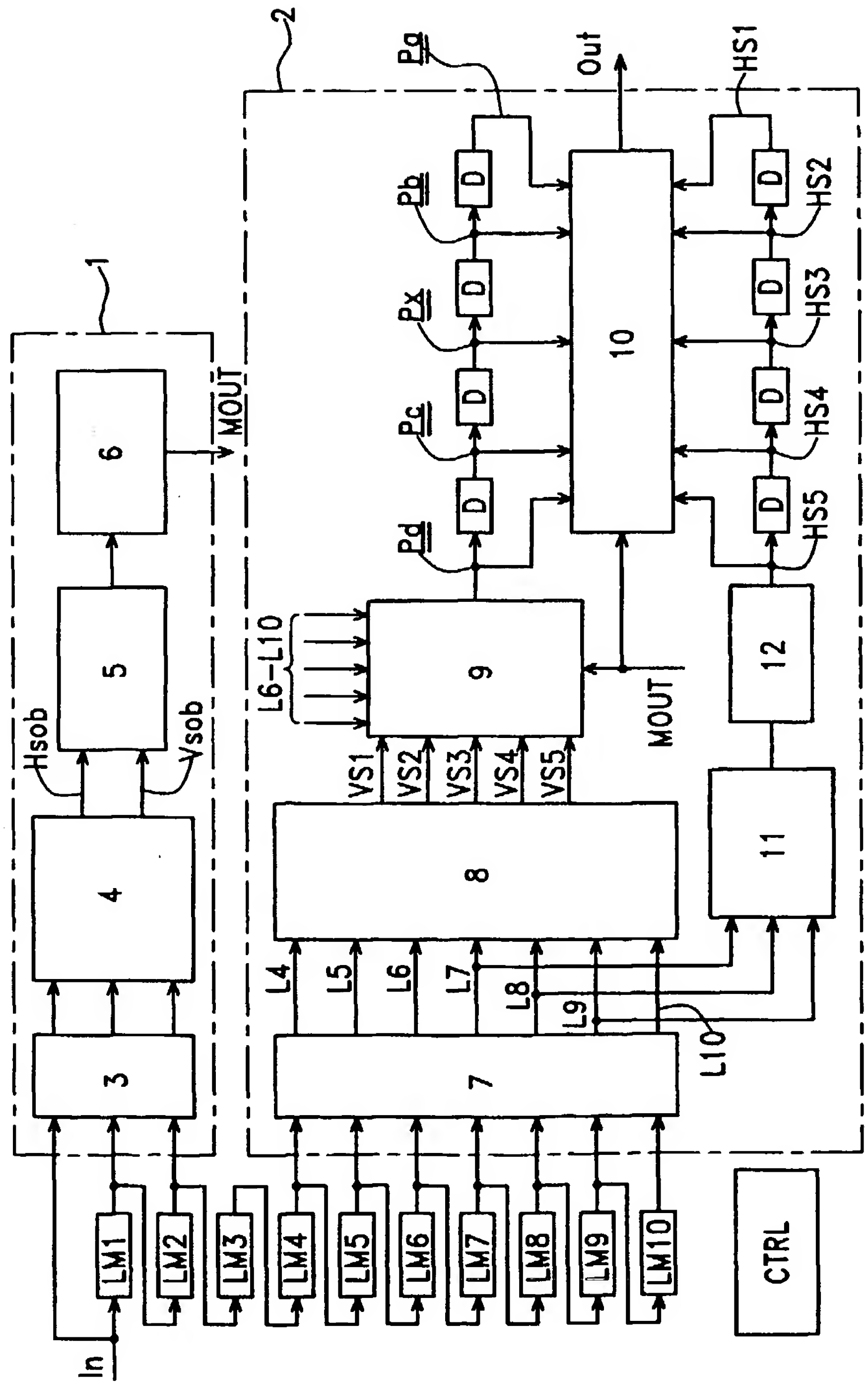


Fig.9



1
2
3
4
5
6
7
8
9
10
11
12
Hsob
Vsob
MOUT
In
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LM2
LM3
LM4
LM5
LM6
LM7
LM8
LM9
LM10
CTRL
L4
L5
L6
L7
L8
L9
L10
L6–L10
VS1
VS2
VS3
VS4
VS5
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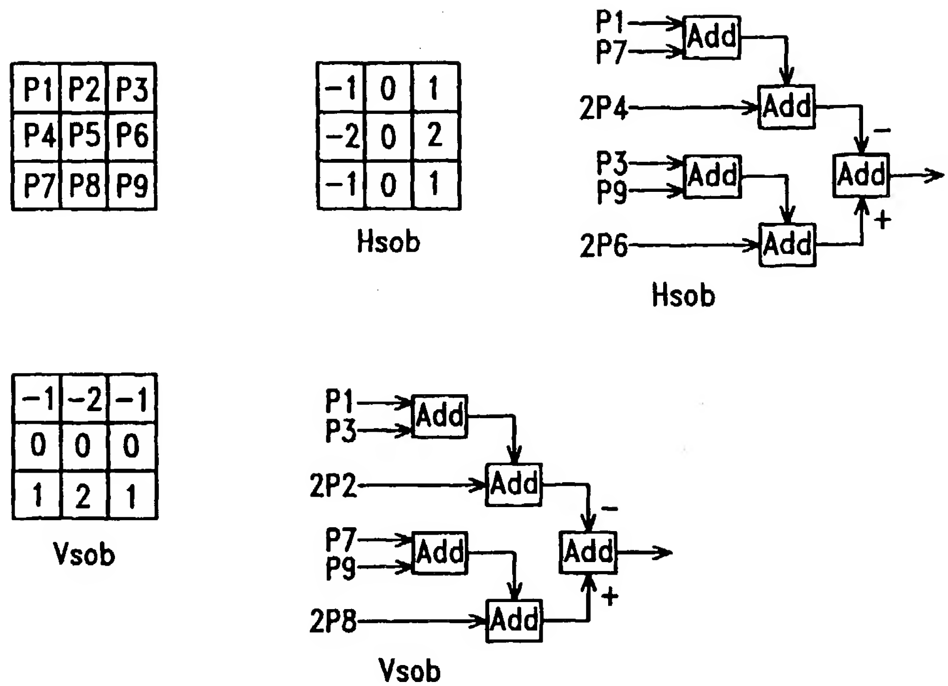
Pa
Pb
Px
Pc
Pd
Out
HS1
HS2
HS3
HS4
HS5

Fig.10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Add
P3
P9
Add
2P6
Add
Add
Hsob
-1 -2 -1
0 0 0
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Vsob
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P9
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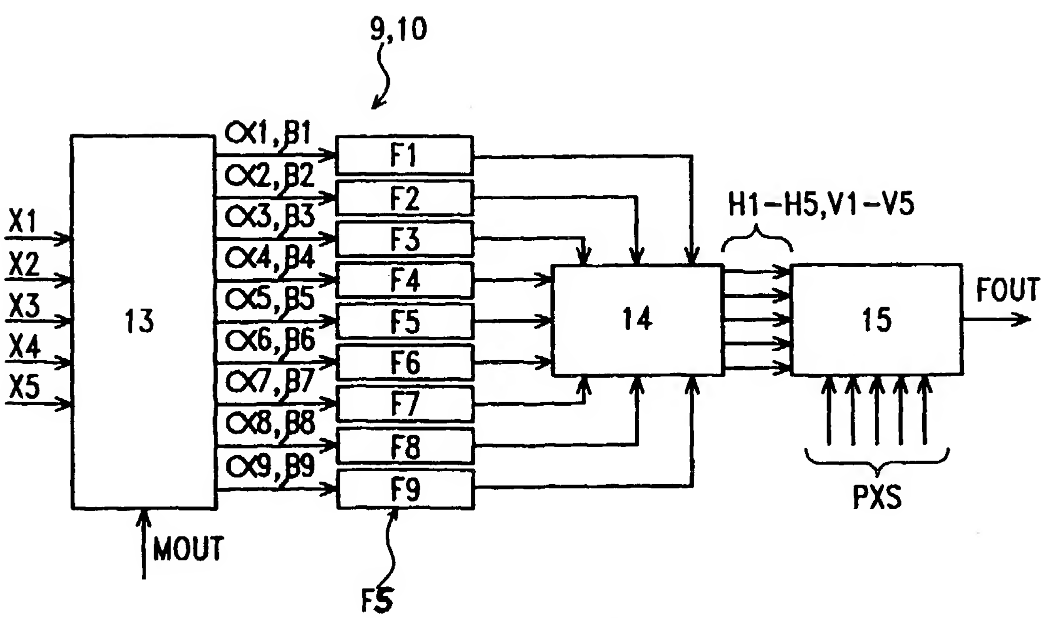
Vsob

Fig.11


9,10
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X2
X3
X4
X5
13
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α3,β3
α4,β4
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α6,β6
α7,β7
α8,β8
α9,β9
F1
F2
F3
F4
F5
F6
F7
F8
F9
F5
14
H1-H5,V1-V5
15
FOUT
PXS

Fig.12

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EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0264

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DERVIAUX C ET AL: "Blocking artifact reduction of DCT coded image sequences using a visually adaptive postprocessing" PROCEEDINGS OF THE 1996 IEEE INTERNAIONAL CONFERENCE ON IMAGE PROCESSING, ICIP'96, vol. II, 16 - 19 September 1996, LAUSANNE, SWITZERLAND, pages 5-8, XP002044085 * page 5, left-hand column, line 1 - page 7, left-hand column, line 21 *	1-4,16	H04N7/30
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X	HIROYUKI OKADA ET AL: "AN ADAPTIVE IMAGE QUALITY IMPROVEMENT METHOD FOR DCT CODING SCHEMES" PROCEEDINGS OF THE PICTURE CODING SYMPOSIUM (PCS), LAUSANNE, MAR. 17 - 19, 1993, no. -, 17 March 1993, SWISS FEDERAL INSTITUTE OF TECHNOLOGY, pages 13.20/A-13.20/B, XP000346472 * page 13.20A, line 14 - page 13.20B, line 23 *	1-4,16	
A	* figure 1 *	5-10, 17-19	

X	US 5 229 864 A (MORONAGA KENJI ET AL) 20 July 1993 * column 2, line 12 - column 2, line 32 * * column 3, line 27 - column 7, line 62 * * figures 1,8 *	1,2,16	
A		3-10, 17-19	

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			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 October 1997	Fassnacht, C

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0264

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 124 (E-1517), 28 February 1994 & JP 05 316316 A (OLYMPUS OPTICAL CO LTD), 26 November 1993, * abstract * * figure 2 *	1	
A		2-10, 16-19	
A	XIAOBING LEE ET AL: "INFORMATION LOSS RECOVERY FOR BLOCK-BASED IMAGE CODING TECHNIQUES - A FUZZY LOGIC APPROACH" IEEE TRANSACTIONS ON IMAGE PROCESSING, vol. 4, no. 3, 1 March 1995, pages 259-273, XP000501901 * page 259, left-hand column, line 1 - page 269, right-hand column, line 8 *	1-21	
A	US 5 442 462 A (GUISSIN RAMI) 15 August 1995 * column 12, line 42 - column 12, line 53 *	1-21	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	MANCUSO M ET AL: "Fuzzy logic based image processing in IQTV environment" IEEE TRANS. ON CONSUMER ELECTRONICS (USA), vol. 41, no. 3, August 1995, pages 917-925, XP002044086 * page 917, left-hand column, line 1 - page 918, right-hand column, line 11 * * figure 2 *	1-21	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 October 1997	Fassnacht, C

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X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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L : document cited for other reasons

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